Can the effectiveness of teaching methods be measured with final exam scores?

A follow-up to last year's poster

Georg Rieger

Physics & Astronomy, UBC

Overview

- Normalized P100 final exam scores with level of difficulty.
- Slightly positive trend reported last year disappears with more refined analysis.
- Refined tools useful for predicting exam scores and learning about question difficulties.

Simple Bloom

Normalized final exam score:

$$\boldsymbol{performance = \frac{exam\ percentage\ \times Bloom's\ level}{average\ Bloom's\ level\ (2.87)}}$$

Cambridge Assessment Tools

CRAS (Complexity, Resources, Abstractness and Strategy), based on the 'Scale of Cognitive Demand' (**SCD**), Greatorex et al., Research Matters, **15** 27 (2013).

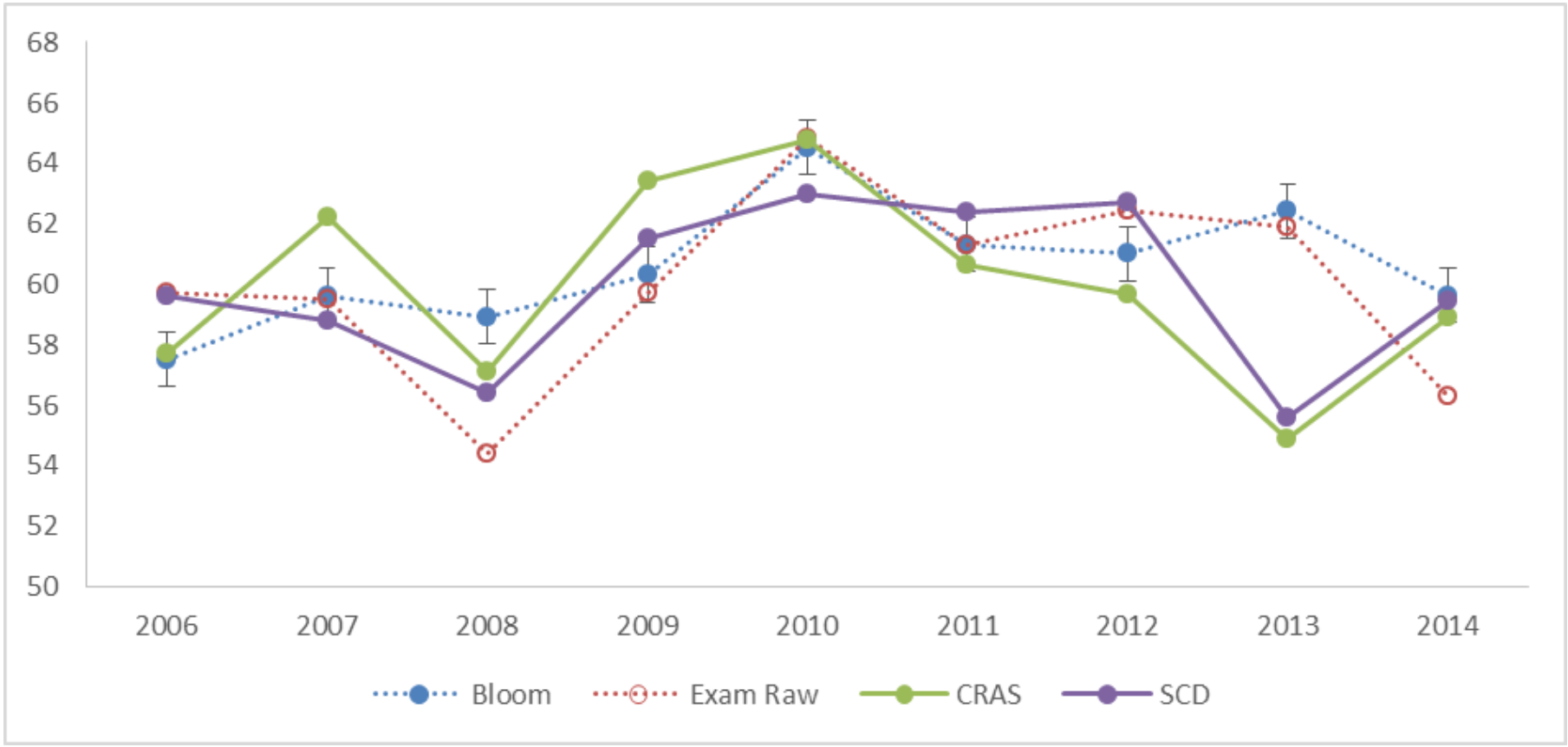
Modifications: interpret and specify scales for certain question types in physics exams.

For example, multiple-answer questions (MA) receive a higher score than multiple-choice questions (MC).

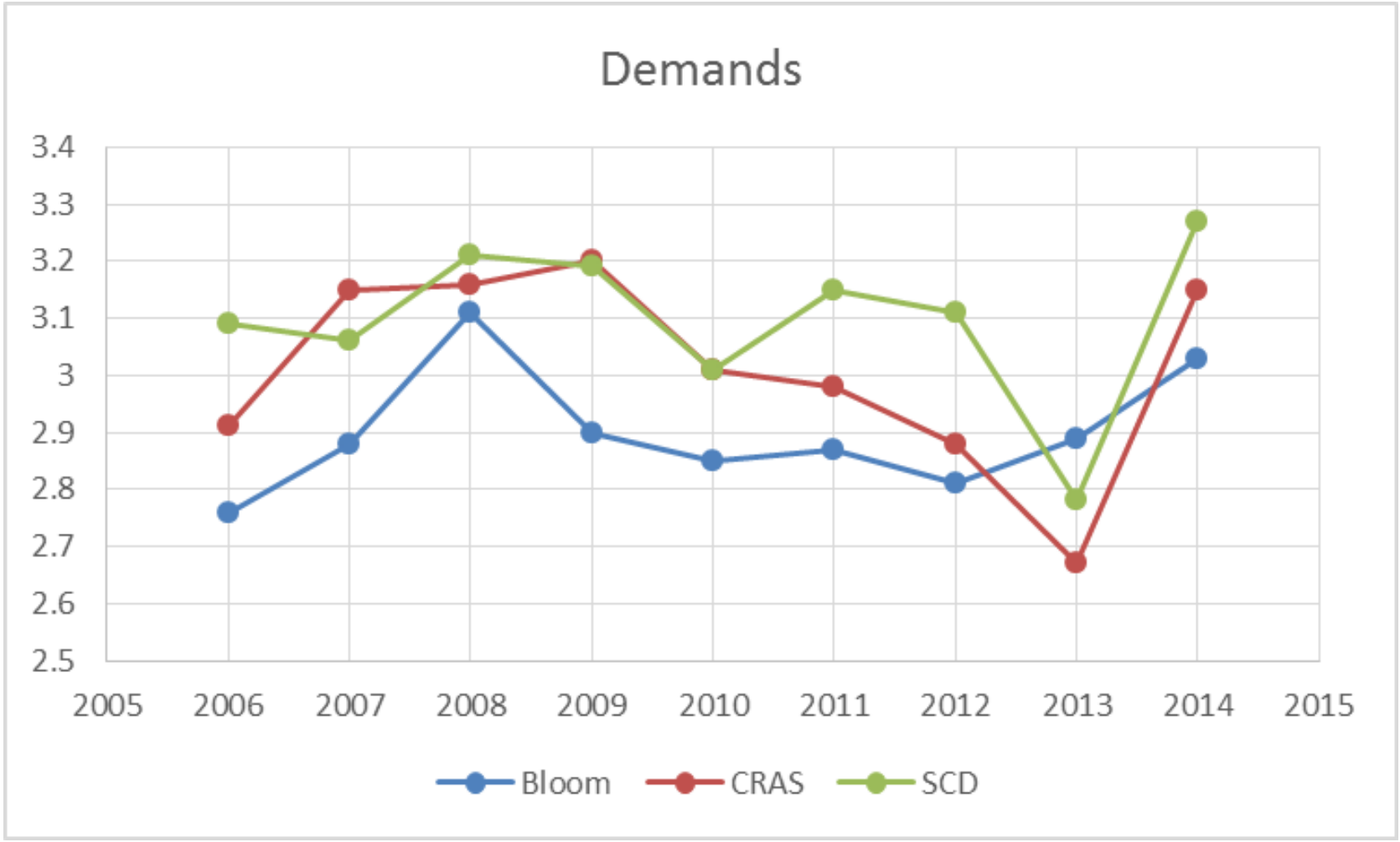
Hard to rate exam difficulty on an absolute scale. Tools useful for a **relative comparison**, e.g. comparing Physics 100 final exams from different years.

One judge might be sufficient for this: "A rater with intimate knowledge of the course is therefore in a good position to come up with a consistent rating of all exam questions. Video: http://www.cambridgeassessment.org.uk/insights/using-the-cras-framework/

Fig. 1: Average final exam percentage and averages normalized by level of difficulty.



Cognitive Demands with Bloom's, CRAS and SCD



Results

- Analysis with Bloom's taxonomy: slightly better exam performance in recent years.
- Analysis with CRAS and SCD: no trend.

- Analysis of P100 2015W final exam draft:
  - Based on previous exam averages, CRAS and SCD scores, predicted an average final exam score of around 55%.
  - Suggested four question that could be simplified (without giving up on testing the topics in question).
  - Predicted score (low 60s) for modified exam matched the average score of 62%.

Carl's Bloom's Level Chart

(Learning Goals workshop, UBC PHAS, May 2007)

Bloom's Taxonomy of the Cognitive Domain
(~= content+skills+habits of mind)

1. Factual Knowledge: remember and recall factual information
   Define, List, State, Label, Name, Describe
2. Comprehension: demonstrate understanding of ideas, concepts
   Describe, Explain, Summarize, Interpret, Illustrate
3. Application: apply comprehension to unfamiliar situations
   Apply, Demonstrate, Use, Compute, Solve, Predict, Construct, Modify
4. Analysis: break down concepts into parts
   Compare, Contrast, Categorize, Distinguish, Identify, Infer
5. Synthesis: transform, combine ideas to create something new
   Develop, Create, Propose, Formulate, Design, Invent
6. Evaluation: think critically about and defend a position
   Judge, Appraise, Recommend, Justify, Defend, Criticize, Evaluate

Higher level: Require deeper conceptual understanding

Bloom's Levels

- Evaluated by single rater (me)

- Two sources:

- Bloom's level chart with action words (from Carl's learning goal presentation)
- Blooming tool (Casagrand and Semsar, U of Colorado, unpublished)

From Greatorex et al., Research Matters, **15,** 27 (2013). I added the colored textboxes.

Figure 1: The Scale of Cognitive Demand: Edwards and Dall'Alba 1981

Characteristic Elements of Groups on the Scale				
Dimensions of Cognitive Demand				
Group	*Complexity*	*Openness*	*Implicitness*	*Level of Abstraction*
1	Simple operations	No generation of new ideas	Data are readily available to the senses	Deals with concrete objects or data stored in the memory
2	Require a basic understanding	↕	Data to be operated on are given	Predominantly deals with concrete objects or issues
3	Understanding, application or low level analysis	Limited generation of new ideas	A large part of the data is given but requires generation of the final outcome	↕
4	** ↕	Generation of ideas from a given data base		Corresponds to concrete-abstract transition
5	Analysis and/ or synthesis	Generation of ideas which are original for the student	Data are not available in a readily usable form – must be transformed	Abstract
6	Evaluation	Highly generative	Require a view of the entity in question as part of a more extensive whole	Highly abstract

** The arrows indicate that the characteristic element is intermediate between two more distinct points on the continuum.

Similar to Strategy in CRAS

Definition-level questions

Basic concepts

Basic interpretation

Intermediate concepts

1-step calculations

2-step calculations

Questions with interpretation of graphs and data

Advanced and/or

Context-rich

Figure 2: The CRAS Framework of Demands: Hughes *et al.*, 1998

	← *Level* →				
Dimension	*1*	*2*	*3*	*4*	*5*
Complexity The complexity of each component operation or idea and the links between them	←	• Simple operations (i.e. ideas/ steps) • No comprehension, except that required for natural language • No links between operations	← →	• Synthesis or evaluation of operations • Requires technical comprehension • Makes links between operations	→
Resources The use of data and information	←	• All and only the data/information needed is given	← →	• Student must generate the necessary data/ information	→
Abstractness The extent to which the student deals with ideas rather than concrete objects or phenomena	←	• Deals with concrete objects	← →	• Highly abstract	→
Strategy The extent to which the student devises (or selects) and maintains a strategy for tackling and answering the question	←	• Strategy is given • No need to monitor strategy • No selection of information required • No organisation required	← →	• Student needs to devise their own strategy • Student must monitor the application of their strategy • Must select content from a large, complex pool of information • Must organise how to communicate response	→

1: Recall definition, facts

2: Simple interpretation or plug in numbers.

3: More difficult concepts or 2 step calculation.

4: Questions involving data from table, graphs or circuits; calculations requiring more than 2 steps.

1: Simple recall without data

2: No additional data required, 1 equation

3: Data must be extracted, 2 equations

4: Assumptions or facts not given needed

1: No technical terms; 2: Kinematics, Forces;

3: Energy, Heat, FBD; Vectors; 4: Circuits, Radiation, Graphs

5: Complex models (Climate, complex circuits, etc)

1: True/False

2: MC 2.5: MA

3: Identify equation, 1 step calculation.

4: Advanced calculation: 2 steps, 2 equations

5: Context-rich problem with more than 2 steps and assumptions.

+1: Data from previous part required

+0.5: If extra or missing information (but not context-rich)